1.0 Introduction

Southern Western Ghats landscape has been identified as global priority hotspot. This unique ecosystem with rich biodiversity has been threatened by ever increasing human pressure. One of the key threats to this landscape is the human-wildlife conflicts, the aftermath of habitat fragmentation. To establish long term ecological security of this landscape requires micro level assessment and monitoring of ecosystem, its dynamics and human demographic growth along with multi stakeholder participation and inter-sectoral coordination.

Human dominated Munnar landscape between Anamalai and Periyar Tiger Reserve has biodiversity rich unique ecosystem with montane shola grassland in a mosaic of cash crops such as tea coffee and cardamom and fuel wood plantations. Though there exists a network of Protected Areas there are fragmented ecosystems in the revenue land which are acting as critical stepping stone habitats (e.g. Anayirangal valley) for wild animals like elephant, guar and large carnivores which frequently interact with the people living in the surrounding villages.

2.0 Present study and Objectives

The overall aim of the present study is to investigate the existing human-elephant interaction particularly the negative interactions leading to conflicts in Munnar landscape at Anayirangal and to put forward the management strategies in an environmental perspective to mitigate the conflicts and to conserve the magnificent Asian elephant, the National Heritage Animal at landscape level.

The study has been oriented in five phases. Initially the status and spatial extent of landscape elements between Anamalai and Periyar Tiger Reserve have been studied and the existing human-elephant conflicting areas have been identified. In the second phase, the status and family structure of elephant population, food resource availability and nutritional status of major elephant foraging species have been studied in the conflict recurrent areas. Ecological investigation and geospatial analysis of human-elephant conflicts have been studied during the third phase. In the fourth phase, habitat utilization, distribution pattern of elephants outside the protected areas of Munnar landscape have been studied in order to know the major viability of elephant population in its ranges. Finally a geospatial model has been developed by integrating the knowledge of elephant habitat preferences and impedances in order to identify the potential elephant corridor connecting the two large natural habitats *viz* the Anamalai and Periyar of Southern Western Ghats landscapes. Conservation and management strategies also have been formulated for the conservation of the magnificent endangered and flagship species.

3.0 Materials and Methods

i. Status, extents and spatial distribution of landscape elements between Anamalai and Periyar Tiger Reserve, Southern Western Ghats.

The spatial extent of landscape elements such as grasslands, shola forests, evergreen forests, deciduous forest, fuel wood plantations, agriculture cash crop plantations, water body, roads, settlements were studied by extensive field work and mapped using the IRS LISS IV remote sensing satellite data. Hybrid classification has been performed by incorporating the accurate field signatures for different land-cover and forest type collected with the aid of GPS (Garmin 76CSX). The protected areas such as National Parks, Wildlife Sanctuaries and Tiger Reserve present in the landscape were also mapped using GPS to know the status of different patches in the landscape.

ii. Status, family structure, density of elephant population and availability of food resource for elephants at Anayirangal, Munnar landscape of Southern Western Ghats.

Elephant population was estimated by direct count methods as well as indirect elephant dung count methods using line transects. The density of elephants in various habitats was assessed by MIKE (Monitoring of Illegal Killing of Elephants), a standard method of estimating elephant density by putting transects and the data was analysed using DISTANCE software. The accuracy of indirect elephant count methods is validated by direct count. Identification of individual elephants has been done and was grouped into respective age and sex classes. The food recourse availability especially the grass biomass in various habitats and the abundance, density of elephant foraging plant species in the shola ecosystems have been estimated by quadrat methods. The percentage of carbon and nitrogen in the major elephant foraging species was estimated by standard methods.

iii. Ecological investigation of human- elephant conflict at Anayirangal, Southern Western Ghats.

Geospatial analysis of Human- Elephant Conflict was done based on five aspects, (i) spatial mapping of intensity of conflicts (ii) correlating the conflicts with environmental variables and identification of human-elephant conflict prone areas (iii) social aspects of human-elephant conflicts (iv) assessment of impacts of human activities on the elephant habitat and (v) correlating the forest fragmentation and Human-Elephant Conflict. The mode of conflicts such as crop damage, property damage and attack on human beings were documented along with the attributes such as the geographical location, date and time, conflicting elephant (herd/tuskers), extent of damage, reasons behind conflicts and the relation with the environmental variables such as slope, distance from water body, distance from roads, distance from settlements and distance from elephant habitats. Based on this, the highest

conflicting areas were mapped and a model has been formulated to identify the conflict prone zone areas. The social aspects of human- elephant conflict were studied by the Participatory Rural Appraisal. To assess the impacts of human activities on elephant habitat, the quantification of wood cuttings, fire wood collection and cattle dung density in the elephant habitat was carried out. Forest cover changes have been studied for the period 1990-2009 and the correlation between changes in forest cover and in intensity of human – elephant conflict has been assessed.

iv. Habitat preference, usage and distribution patterns of Asian elephant in fragmented forest areas and plantations in Munnar landscape, Southern Western Ghats.

The elephant habitats were categorized into six vegetation class. The percentage of elephant dung density in these vegetation class were assessed and forage preference raster is generated incorporating the percentage of available biomass in these habitats using GIS software by multicriterion weighted (Analytic hierarchy process - AHP) overlay analysis. The local movement paths of elephants were mapped by tracking the elephant (both herd and tuskers) with GPS. Similarly preference raster for water bodies, slope and protected areas were developed. Finally habitat preference map was prepared integrating all the preference raster. The major disturbances such as road, settlements, slopes and other developmental activities such as windmill construction and resorts were also mapped and multicriterion weighted (AHP) overly were used to develop an impedance map.

v. Identification of potential elephant corridor between Anamalai and Periyar Tiger Reserve, Southern Western Ghats landscape, a geospatial approach.

A geospatial model has been developed by integrating the generated elephant habitat preference raster and impedance raster based on least cost principle to identify the potential elephant corridor connecting the two landscapes, Anamalai and Periyar. Connecting these two landscapes will be beneficial to the elephants which are going to be isolated at Anayirangal valley and they will get an access to the nearby natural elephant habitat so that the existing severe Human-Elephant Conflict in the valley can be reduced to a greater extent. The generated potential elephant corridor has been evaluated by field verification and the accuracy of it has been estimated. Finally a conservation strategy has been developed to conserve the Asian elephant at Munnar landscape.

4.0 Results

The major landuses and forest cover classes of Munnar landscape and Cardamom Hill Reserve are the agriculture with mixed crop cultivation (30.86%), grassland (14.29%), cardamom plantation (14.19%), tea plantation (8.91%), montane shola forest (7.87%), dry deciduous forest (6.01%), fuel wood plantations (4.5%), evergreen forest (4.15%), moist

deciduous forest (3.93%), scrub jungle (2.15%),coffee plantation (1.49%), settlement (1.23%), water body (0.37%) and semi evergreen forest (0.04%).Only 26.33% of grassland, 30.30% area of montane shola forest have got protection status and majority of evergreen forest (97.61%), eucalyptus (93.06%), wattle (80.60%), pine (100%)scrub jungle (94.23%), dry deciduous forest (69.70%) and moist deciduous forest (68.95%) are outside the protected area. This clearly indicates that most of the elephant habitats are outside the protected area and the chances of Human-Elephant Conflict in these areas will be high.

The elephant population estimated by direct count and indirect elephant census method shows a resident population of 29±3 elephants. This population has 11 males and 18 females of different age groups with skewed adult male to female ratio of 1(adult male): 2.25 (adult female), which is unique in Western Ghats. Such abnormal sex ratios and the observed birth to death ratio of 1:1 do not bode well for the future growth of these populations and gives a big admonition of the viability of population. The average elephant dung density is 5486/km² and the average elephant density is 3.84/km²; both are high in eucalyptus plantation. A total of 26 species of grass were identified from various elephant habitats and the major dominant grass species are *Pennisetium purpurem, Cymbopogon citrtius, Andropogon lividus, Cyperus pangorei, Phoenix loureirii and Chrysopogon zeylanicus.* Grassland habitat and eucalyptus plantation has the highest peak grass biomass at Anayirangal.

A total of 1261 incidents of conflicts occurred either in the form of crop damage, property damage or attack on human beings between 2007 and 2009. Elephant raid in various settlements of Anayirangal had resulted with a net loss of □ 874752. Net economic loss for agriculture damage was estimated high for the year 2008 (□32, 08,717) followed by 2009 (□19, 30,012) and 2007 (□17, 36,023). The percentage of farmers affected is high in the settlements where the farmers having small scale cultivation of both cash crops and food crops. A total of 164 property damage incidents occurred at Anayirangal valley and was high in 2008 as the newly established tribal settlements started constructing their sheds and houses during this time. A total of 117 incidents of attack on human have been reported between 2007 and 2009. During this period 5 people were killed by the elephant, 11 people were severely injured and 93 got minor injuries. Out of five human deaths two were females.

The analysis of the frequency of conflicts with respect to various environmental variables reveals that the conflict decrease with increase in distance from road, streams, waterbodies, settlements, fuel wood plantations, cardamom plantations and grasslands and increases with decrease in altitude, slope and increase in distance from shola forest. The geospatial analysis of conflicts shows 85% of the settlements at Anayirangal fall under high conflict prone zones except Pachapulkudi, Pethotti and Mulathara.

The rate of forest fragmentation and conversion of shola forest, grasslands and fuel wood plantations was high between 1990 and 2008, which leads shrinkage of crucial elephant habitats as well as blocking the usual movement paths of elephant resulted high conflict condition. The over exploitation of elephant habitat by conversion of natural vegetation to settlements, resort areas and agriculture land along with other biotic pressure such as looping of trees, fire wood collection and cattle grazing inside the elephant habitat resulted the elephants to live in a stressed and fragmented habitat which intern increase the conflicting condition at Anayirangal.

A corridor has been generated using a combination of preference and impedance layers to elephant movement between Anamalai and Periyar. The proposed elephant corridor has a length of 88.4 km and a width of 50 m. The corridor passes through the highly fragmented Munnar landscape. The remnant shola forests and eucalyptus plantations inside the tea estates and the grasslands in the Kurinjimala Wildlife Sanctuary, Mannanmala, Meesapulimala, Thondimala, Njandar, Chathurangappara, Kottamala and Ramakkalmedu area play great role in the movement path. Anayirangal valley, Mathikettanshola National Park and the deciduous forest and scrub jungle of Theni and Kambam Valley Reserve Forest in eastern slope of Western Ghats act as a crucial link of the corridor between Chinnar Wildlife Sanctuary and Periyar Tiger Reserve. About 31 km (35%) of the corridor pass through the highly fragmented and fragile landscape elements outside the protected areas and remaining through the protected areas. The vegetation class III forms 50.67% of the corridor area of which 85.90% has got protection status.

5.0 Summary and Conclusion

Once existed harmony of people living with elephants in the Munnar landscape has now become topsy-turvy. The over exploitation and habitat conversion into stepping stone habitats leads the local abundance of elephants and high conflicts with people at Anayirangal. Unscientific land allotment for landless tribal triggers the rate of conflicts. The highly preferred elephant habitats are outside the protected area which addresses the urgency for making immediate measures to protect those areas. The remnant forest patches and montane shola-grasslands in the Munnar landscape, catchments of Anayirangal reservoir along with Mathikettanshola National Parks, the cardamom plantations especially part of Mulathara, Thondimala, Thalakkulam, Njandar, Gloria farm and Kudampara estates at the western slopes, the grasslands at the crest and the attenuating scrub jungle in the eastern slopes of Western Ghats which are along the track of proposed elephant corridor are the vulnerable links between Anamalai and Periyar. Managing these entire landscape as a matrix supporting the whole biotic community will ensure the conservation of Asian elephants which intern reduce the conflicts especially at Anayirangal and nearby areas.